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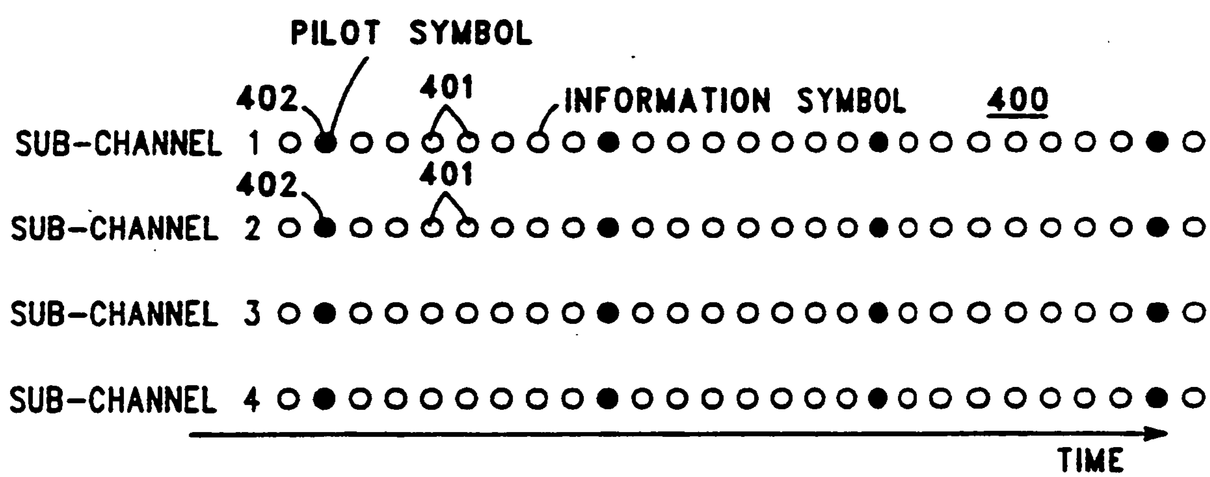
(54) Title: COMMUNICATION SIGNAL HAVING A TIME DOMAIN PILOT COMPONENT



(57) Abstract

A quad 16 QAM transmission and reception methodology wherein a time domain pilot reference is advantageously associated therewith. There may be one or more such pilot references (402) for each packet of multiple 16 QAM pulses. Depending upon the embodiment, each 16 QAM pulse can include a time domain pilot reference, or an estimated pilot reference for that pulse can be d termined either by reference to pilot references in other pulses sharing the same packet, or by reference to pilot references for other previously received 16 QAM pulses corresponding to that same pulse.

COMMUNICATION SIGNAL HAVING A TIME DOMAIN PILOT COMPONENT

Technical Field

This invention relates generally to communication methodology, and more particularly to communication signals having information components that require the presence of a pilot component in order to facilitate recovery of the information components.

Background of the Invention

Various communication systems are known in the art. Pursuant to many such systems, an information signal is modulated on to a carrier signal and transmitted from a first location to a second location. At the second location, the information signal is demodulated and recovered.

Typically, the communication path used by such a system has various limitations, such as bandwidth. As a result, there are upper practical limitations that restrict the quantity of information that can be supported by the communication path over a given period of time. Various modulation schemes have been proposed that effectively increase the information handling capacity of the communication path as measured against other modulation techniques. For example, a 16 point

existing in the time domain, as distinguished from the frequency domain pilot components discussed above.)

Though suitable for many applications, QAM transmissions that include time domain pilot components are not satisfactory in all applications. For example, in an RF communication environment, where communication units may be in motion with respect to one another, such prior art time domain pilot reference QAM methodologies may provide unacceptable performance. In particular, the land-mobile radio channel is characterized by multipath fading that causes the channel phase and amplitude to vary over time as the receiving or transmitting unit moves about. Such variations must be compensated or otherwise allowed for in order to provide proper reception. Typically, phase and frequency modulation schemes avoid the need for compensation since channel amplitude variations can be ignored and differential or discriminator reception techniques can automatically account for the channel phase variations. However, phase and frequency modulation are not very bandwidth efficient. While QAM techniques can introduce bandwidth efficiency by comparison, QAM requires more complicated channel compensation methods, such as those prior art techniques that use one or more pilot tones in association with the information content.

Another problem associated with the multipath nature of the radio channel is that of frequency-selective fading. This occurs whenever the delay difference between the various multipath components that arrive at the reciever become large enough relative to the signalling rate in the channel. When this happpens,

eff ctively recover a signal corresponding to the original information signal.

In one embodiment of the invention, the original information signal can be in the form of a serial data stream, and the conversion step operates upon preselected serial portions thereof.

In one embodiment of the invention, the conversion step further includes converting groups of bits that comprise the original information signal into corresponding multibit symbols. In a further embodiment, a predetermined plurality of these symbols constitutes a processed information signal sample sequence.

In one embodiment of the invention, the combining step includes combining the predetermined sample (which represents the time domain pilot reference) with at least two of the sample sequences. In another embodiment, all of the sequences are combined with a pilot tone reference in this manner.

In yet another embodiment, the time domain pilots can be provided in some, but not all, of a group of subchannels. To provide for channel compensation in the subchannels that do not have a pilot, the time domain pilots that are provided can be utilized to provide an estimation of a pilot for that subchannel. In effect, then, the occassionaly sent pilots can be utilized to interpolate both over time and over frequency to allow for channel compensation of the information signals.

Brief Description of the Drawings

processor, such as from the Motorola DSP 56000 or DSP 96000 families, is readily programmable to accomplish the functions set forth below. Also, although described below in the context of a 16#QAM application, it should also be understood that the teachings herein are also applicable for use with other modulation schemes as well.

A processing unit (102) receives an original information signal (101). In this particular embodiment, this information signal constitutes a serial bit stream having an effective baud rate of 53.2 kilobits per second. This bit stream can represent, for example, true data, digitized voice, or other appropriate signals.

The processing unit (102) functions to convert groups of16 serial bits of the original information signal into four 16 QAM complex signal points (symbols). For example, Fig. 2 depicts a 16 QAM complex signal symbol constellation (200). Each symbol in the constellation represents a different combination of four serial bits. For example, a first one of these symbols (201) represents the bits "0001." A second symbol (202), on the other hand, represents the bits "0100," all in accordance with well understood prior art methodology.

For each serially received 16 original information bits, the processing unit (102) outputs, in parallel, on each of 4 signal paths (103-106), an appropriate representative multibit symbol as described above. A pilot insertion unit (107-110), located in each signal path (103-106), inserts a predetermined symbol following receipt of 7 serially received information symbols from the processing unit (102) pursuant to one embodiment of a communication methodology in

the form $e^{(j2\Pi f_{offK}t)}$, wherein j is the square root of negative one, t is time, and f_{offk} comprises an offset frequency corresponding to the kth composite signal. All of the above parameters will be identical for each of the injection signals (126-129) with the exception of the frequency offset value. In this embodiment, the first injection signal (126) has an offset frequency value of minus 6.27 kHz. The second injection signal (127) has an offset frequency of minus 2.09 kHz. 2.09 kHz comprises the offset frequency for the third injection signal (128), and 6.27 kHz comprises the offset frequency for the fourth injection signal (129).

The filtered and offset composite signals are thereafter combined (131) to form a modulation signal. The real and imaginary parts of this complex modulation signal are separated (132, 133) and provided to a quadrature upconverter (134), following which the signal is amplified (135) and applied to an antenna (136) for transmission, the latter occurring in accordance with well-understood prior art methodology.

The resultant shaped, frequency offset, and combined 16 QAM symbol sequences are generally represented in Fig. 5 by reference numeral 500. As generally depicted in this spectral diagram, there are four effective sub-channels of symbol information (501), each being offset from the others in correlation to the offset frequencies referred to above. In this embodiment, each subchannel symbol also includes a time domain pilot reference sequence (figuratively represented by reference numeral 502) embedded therein. (It is not necessary that each 16 QAM subchannel symbol of this quad 16 QAM packet include an

A receiver pulse shaping filter (607) receives this mixed signal and appropriately shapes the received signal and filters out the other subchannel signals and noise to produce a single subchannel signal. A symbol sampler (608) then allows individual symbols to be sampled and provided to both of two processing paths (609 and 610). The first signal processing path (609) includes a pilot sampler (611) that selects the pilot symbols from the composite symbol sequence comprising data and pilot symbols. The pilot samples are then multiplied (612) by the reciprocal (613) of the original transmitted pilot symbol (which is known at the receiver by virtue of having been predetermined), to provide an estimate of the channel gain corresponding to the pilot sampling instant.

A pilot interpolation filter (614) then processes this recovered pilot sequence to obtain an estimate of the channel gain at the intervening data symbol instants.

Compensation of channel phase and amplitude distortion and recovery of the original data symbols are carried out as follows. Delay (616) provided in the second processing path (610) serves to time-align the estimated channel gains with the corresponding data symbols. The delayed data symbols are multiplied (617) by the complex conjugates (618) of the estimated channel gains. This operation corrects for channel phase but results in the symbol being scaled by the square of the channel amplitude. This is taken into account in the decision block (619) with appropriate input from a threshold adjustment multiplier (621) that itself utilizes nominal threshold information and a squared

one another on a carrier. In ffect, pursuant to this embodiment, the various subchannels described above would each carry information symbols that are independent of the other subchannels, but wherein the time domain pilot symbol(s) are interpolated over time (and frequency, if desired, as described above) to estimate channel conditions to thereby assist in the proper recovery of the information symbols from the various subchannels.

What is claimed is:

2. The method of claim 1 wherein the step of combining at least one of the parallel plurality of processed information signal sample sequences with at least one predetermined sample includes the step of combining each of the parallel plurality of processed information signal sample sequences with at least one predetermined sample.

3. The method of claim 2 wherein the step of combining each of the parallel plurality of processed information signal sample sequences with at least one predetermined sample produces a plurality of composite signals.

4. The method of claim 1, wherein the step of combining at least one of the parallel plurality of processed information signal sample sequences with at least one predetermined sample includes the step of combining at least two, but not all, of the parallel plurality of processed information signal sample sequences with at least one predetermined sample to provide at least two composite signals.

5. The method of claim 4 and further including the step of:

C) mixing each of:

the composite signals; and

those of the parallel plurality of processed information signal sample sequences that were not combined with at least one predetermined sample; with an offset signal to produce a plurality of offset signals.

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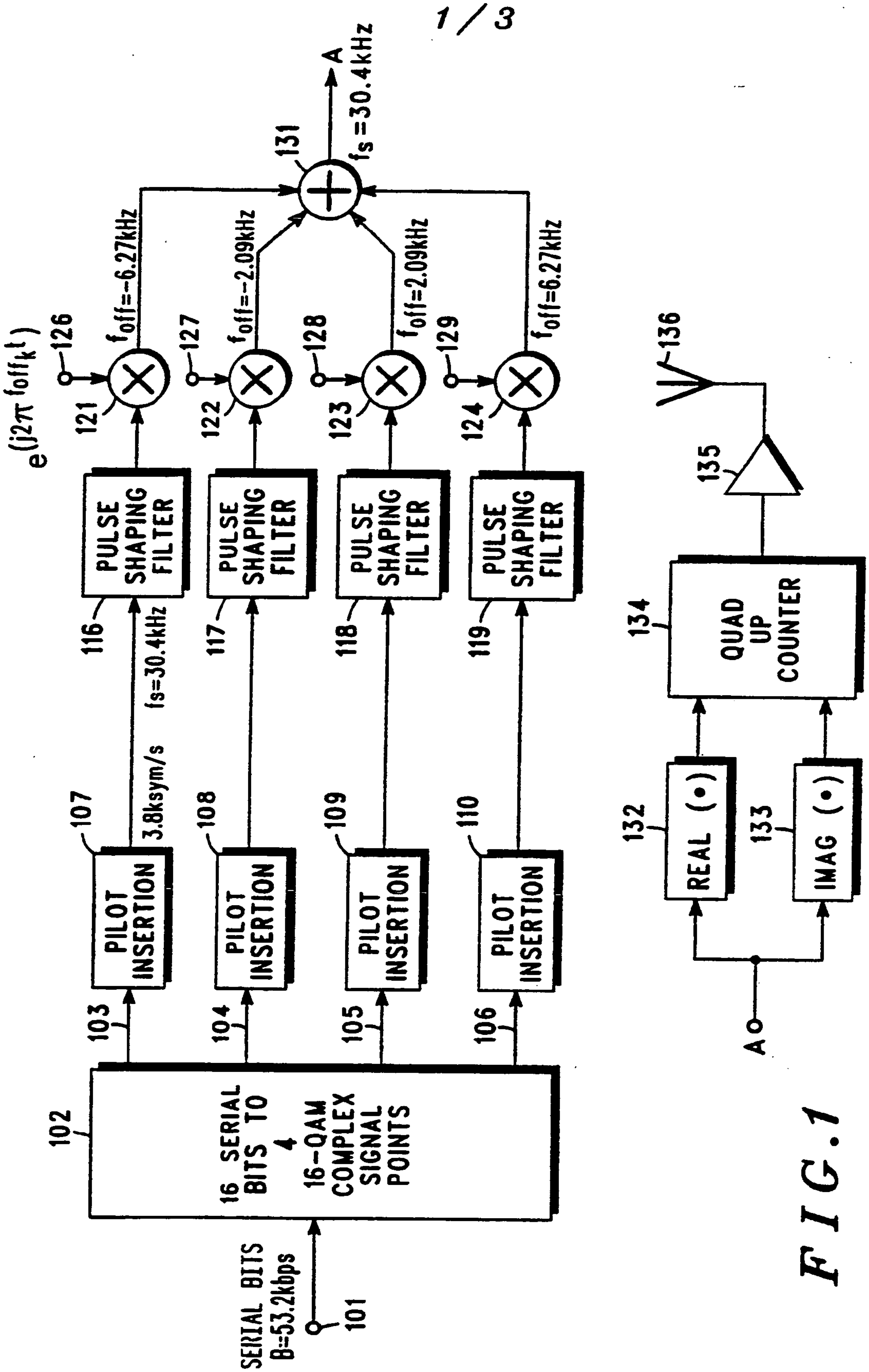


FIG. 1

SUBSTITUTE SHEET

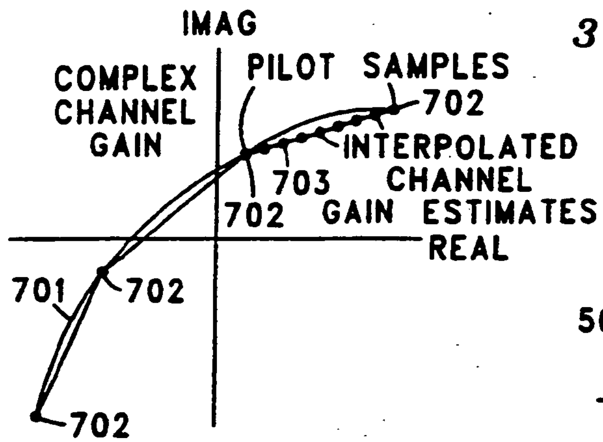


FIG.7

FIG.5

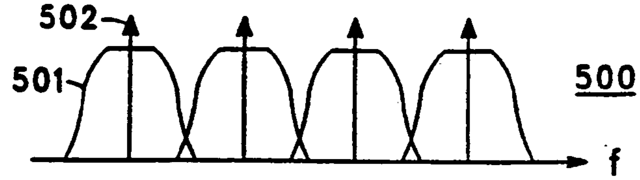
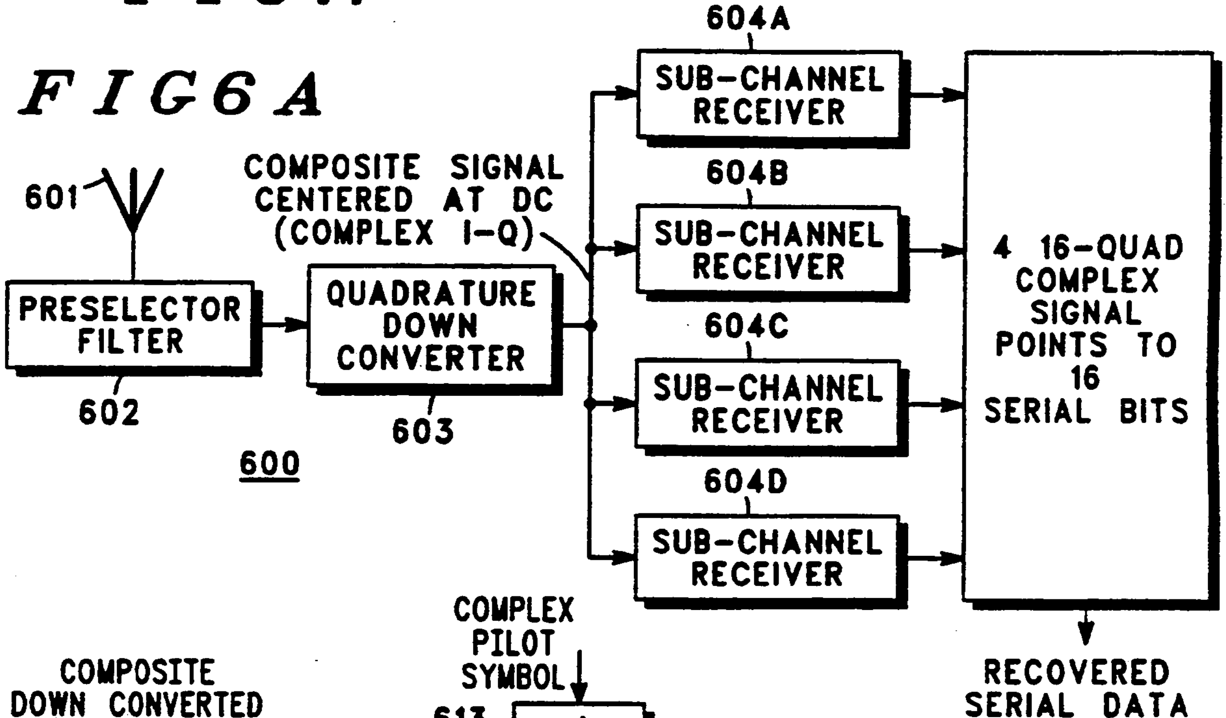


FIG6A



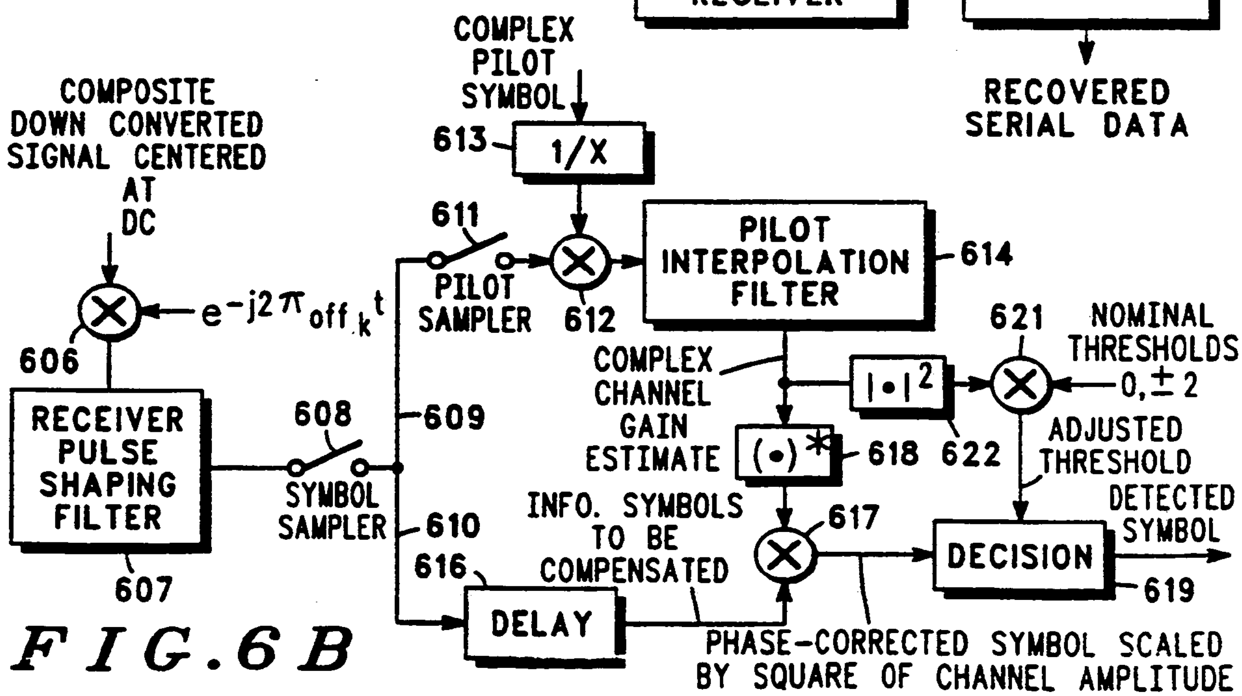


FIG.6B